STABILIZING ATMOSPHERIC CONCENTRATIONS OF CO2: ROLE OF CARBON SEQUESTRATION

Presented at:
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INTRODUCTION

During the Second Annual Carbon Sequestration Conference, the Department of Energy set forth its initial vision for a "Pathway to Stabilization" of carbon emissions for the U.S.:

- Reducing energy intensity by 18% by 2012,
- Then, further slowing the growth in GHG emissions, stopping this growth by 2025, and reversing it after 2040.

In this pathway, energy efficiency and renewables, reductions in non-CO2 GHGs, and particularly the capture and storage of CO2 were expected to carry the great bulk of the emission reduction burden.

EXPECTED GROWTH IN EMISSIONS

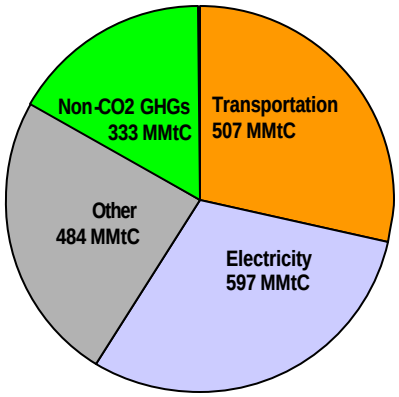
Even though the carbon intensity of the U.S. economy is expected to decline by more than half, economic and population growth cause GHG emission to increase significantly by 2050 (Reference Case):

Year	GHG Intensity (tC/MM$GDP)	GHG Emissions (MMtC) CO2	GHGs
2001	208	1,588	1,921
2012	177	1,880	2,290
2025	151	2,270	2,790
2050	98	2,640	3,360

Source: EIA/AEO 2004 to 2025; projections by authors to 2050.

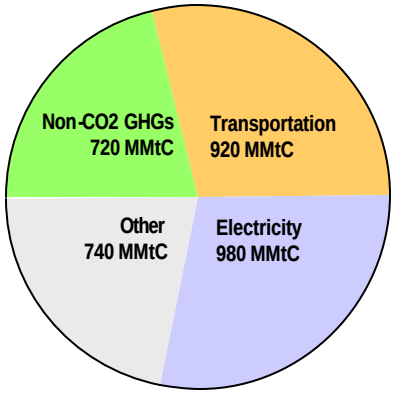
SOURCES OF GHG EMISSIONS: TODAY AND IN 2050

Current (2001)



1,921 MMtC

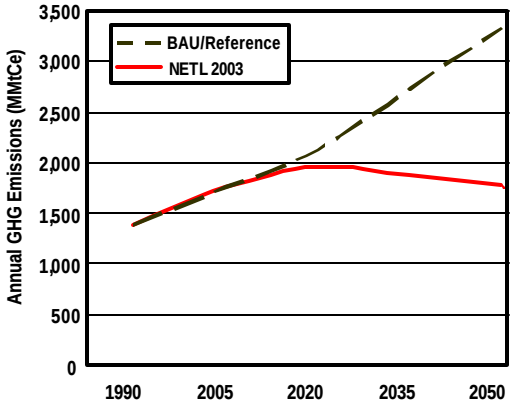
Reference Case Year 2050



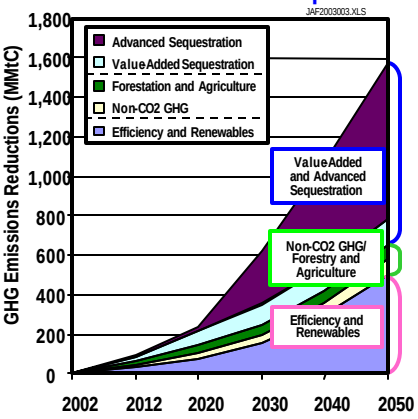
3,360 MMtC

PATHWAY TO STABILIZATION OF ATMOSPHERIC EMISSIONS

Reduced Emissions Scenario (CO2 Only)



Contribution of Emission Reduction Options



Source: NRDC, May 2003

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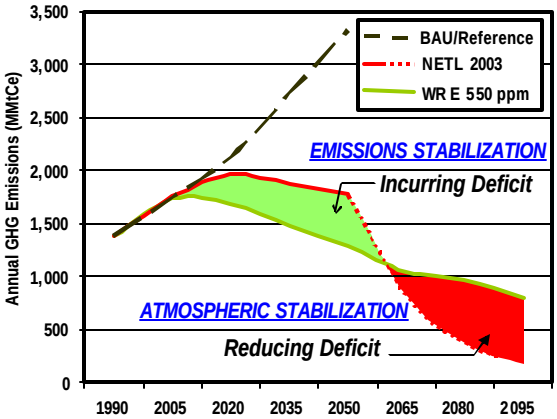
IMPACT OF DELAY ON STABILIZATION OPTIONS

- **During this conference, David Hawkins (NRDC) pointed out that the delays inherent in the DOE/NETL "stabilization of CO2 emissions" option could pose serious constraints during the second half of this century.**
- **He challenged DOE/NETL to consider a more aggressive "pathway", holding GHG concentrations below the 550 ppm WRE scenario.**



Source: Adapted from NRDC, May 2003

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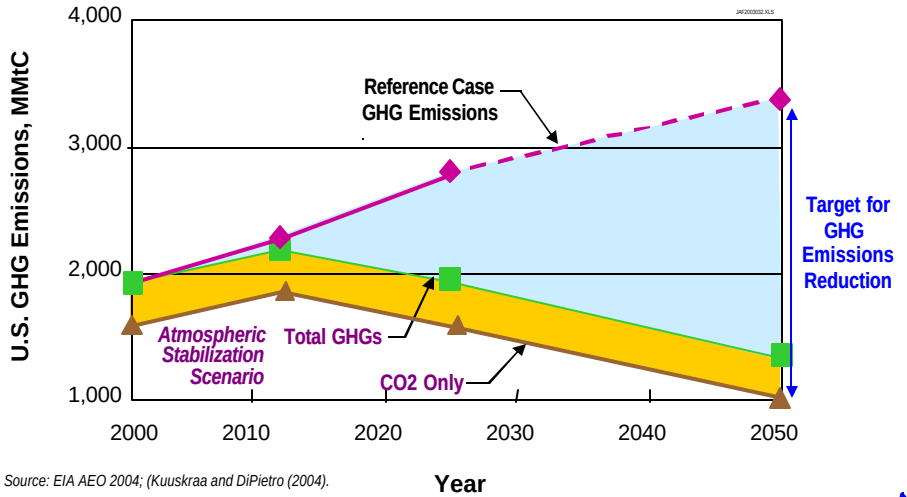
PATHWAY TO STABILIZATION OF ATMOSPHERIC CONCENTRATIONS

In response to this challenge and on behalf of the DOE/NETL, the authors of this presentation have examined a second "pathway" for the U.S., one leading to stabilization of atmospheric carbon concentrations:

- **First, stabilizing annual GHG emission by year 2025 at or below year 2001 levels (1.9 GtC) of carbon by 2025;**
- **Then, reducing annual GHG emissions to 1.2 Gt of carbon by 2050.**

REFERENCE CASE AND ATMOSPHERIC STABILIZATION, U.S. GHG EMISSIONS



Source: EIA AEO 2004; (Kuuskraa and DiPietro (2004).

STUDY QUESTIONS

A series of questions are being addressed by this study of stabilizing atmospheric concentrations of carbon:

- ***Are such deep reductions in GHG emissions possible without a major dislocation in the U.S. energy industry?***
- ***Can these deep reductions be achieved at moderate costs to the domestic economy?***
- ***What will need to be the role of carbon sequestration and other GHG emissions reduction and control technologies?***

KEY ASSUMPTIONS

1. Efficiency, renewables and reductions in non-CO_2 GHGs are each expected to play a major role.
2. CO_2 capture from high concentration industrial CO_2 vents and storage with EOR/EGR builds the essential CP2 capture and storage infrastructure.
3. Capital stock turnover retires old, inefficient power plants. Lower cost carbon capture is applied aggressively to new power plants built after 2012.
4. Vehicle mileage efficiency improves substantially with technology and less use of older cars. Production of hydrogen (with CO2 capture) is increasingly used after 2025 for transportation and other energy applications.
5. Economic incentives (equal to a shadow price of $50 per metric ton of carbon) and efficiency standards are used to provide signals to the market.

UPGRADES TO THE ANALYSIS METHODOLOGY

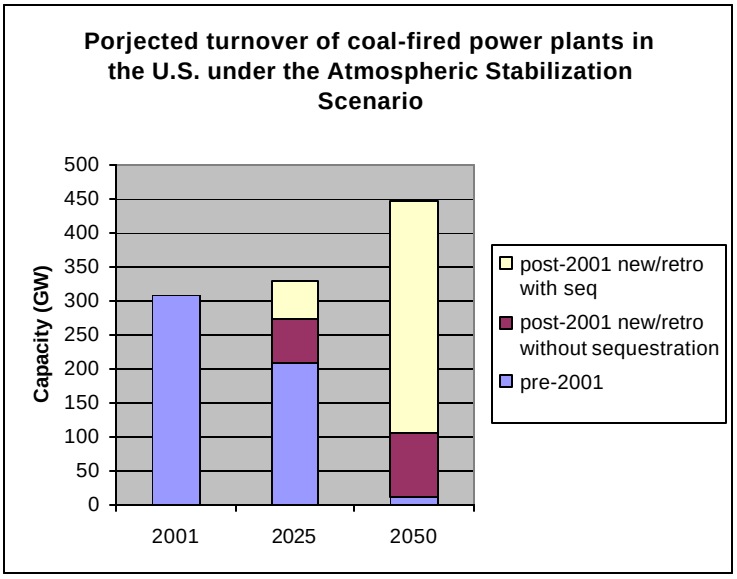
- **Expanded number of GHG emissions reduction options considered in detail and quantified**
  - Improved vehicle fuel efficiency
  - Improved power plant efficiency
  - Reduced transportation per GDP
  - Reduced electricity consumption per GDP
  - Non-hydro renewables
  - Hydrogen energy systems
- **The limits of capital stock additions and turnover applied to**
  - supply of CO2 from vents and power plants
  - emissions reduction from improved efficiency from power plants
- **Revised cost supply curves for terrestrial sequestration and non-CO2 GHG emissions mitigation**

CAPITAL STOCK TURNOVER

<u>Electricity</u>. Significant retirement of older, domestic power plants is expected by 2050:

• Coal Plant Retirements	296 GW out of 307 GW (in current use)
• Natural Gas Plant Retirements	All 64 GW of Combined Cycle (in current use)

<u>Transportation</u>. Nearly 80% of passenger car vehicle miles traveled by automobiles in 2050 is in cars of 5 years old or less of age.



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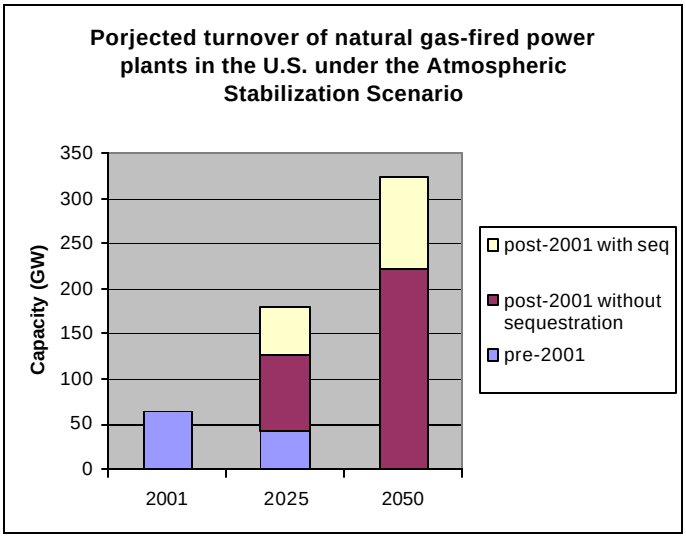

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WHAT WILL THE U.S. LOOK LIKE?

1. ***Transportation (2050):***
   - **Advanced hybrid engine technology and "stock turnover" provide a composite light-duty vehicle fleet efficiency of 54 mpg.**
   - **Industry's fuel efficiency goals for heavy duty trucks and aircraft are met by 2025, with further improvements by 2050.**
   - **Aggressive installation of public transportation and "smart highways".**
   - **CAFE standards follow commercial availability of advanced transportation technology.**

2. ***Electric Power Generation (2050):***
   - **Non-hydro renewables increase by nearly twenty fold, to 850 Bkwh/yr.**
   - **Coal and natural gas-fired power plants achieve a composite efficiency of nearly 63%; new (post 2025) coal and natural gas plants reach 54% and 67% efficiencies (including CO2 capture).**
   - **Hydro and nuclear power remain at about 300 and 800 Bkwh/yr, respectively.**

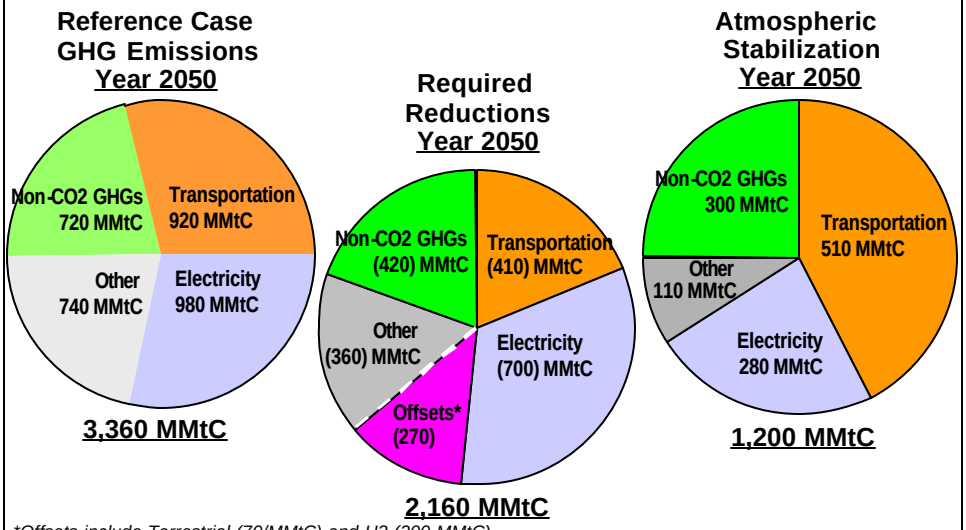
WHAT WILL THE U.S. LOOK LIKE?

3. ***Carbon Capture and Storage (2050):***
   - **Carbon capture is used by 70% of new coal-fired power plants built between 2012 and 2025 and 90% of new plants built after 2025.**
   - **Domestic oil production is increased by 2 to 3 million barrels per day from use of captured CO2 for enhanced oil recovery.**

4. ***Non-CO2 GHG Gases (2050):***
   - **Industrial source methane emissions are essentially eliminated.**
   - **Improved agriculture practices reduce nitrous oxide emissions.**
   - **Substitutes are developed for high GHG potential gases.**

5. ***Other (2050):***
   - **Forest and land carbon sinks are saturated at 70 MMtC per year.**
   - **Great majority of high CO2 concentration industrial vents are captured.**
   - **Widespread use of "high efficiency appliances" and CHP in the residential, commercial and industrial sectors.**

REALIZING THE STABILIZATION OF ATMOSPHERIC CONCENTRATIONS GOAL?



*Offsets include Terrestrial (70/MMtC) and H2 (200 MMtC)

CONCLUSIONS

A "technology and policy rich" portfolio of initiatives will be required to provide a moderate cost pathway toward atmospheric stabilization of GHG concentrations.

Improvements in vehicle efficiency, sharp reductions in non-CO2 GHGs and new energy systems (i.e., hydrogen for transportation) are all part of the solution.

Carbon capture and storage will need to play a major role, providing over one-third of the required reductions.

Development of lower cost CO2 capture technology and combining CO2 storage with EOR/EGR are two important first steps.

HOW TO ACHIEVE GOAL?

A portfolio of emission reduction actions will be required to reach the stabilization of atmospheric concentrations goal, with carbon capture and storage directly providing over one-third (740 MMtC) of the reductions.

	2050 Reference Case	Reduction	2050 Atmospheric Stabilization
Electricity	**980**	**(700)**	**280**
• Increased Renewables/Reduced Demand		(100)	
• Improved Power Plant Efficiency		(170)	
• Power Plant CO2 Sequestration		(430)*	
Transportation	**920**	**(410)**	**510**
Other/Offsets	**740**	**(630)**	**110**
• CO2Vents/Sequestration		(110)*	
• Other/Efficiency / Reduced Demand		(250)	
• Terrestial Offsets		(70)	
• Hydrogen w/CO2 Sequestration		(200)*	
Non-CO2 GHGs	**720**	**(420)**	**300**
	3,360	(2,160)	1,200

**Components of direct CO2 capture and storage.*

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